Size Reduction

As per D.Pharmacy New Syllabus ER 2020

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Size Reduction

1. Pharmaceutical powders are classified as monodispersed (particles of same size) as well as polydispersed (particles of different sizes).
2. Particles of monodispersed type are ideal for pharmaceutical applications whereas polydispersed powders create considerable difficulties in their processing for production of dosage forms.
3. In order to obtain uniform size particles, powders are to be reduced in their size by size reduction.
4. Size reduction involves techniques to create new surfaces and increase surface area by adding energy proportional to the bonds holding the feed particles together.

Definition:

- Size reduction is defined as a process of reducing large solid unit masses (vegetable or chemical substances) into small unit masses, coarse particles or fine particles.

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Objectives:

- The main objective of size reduction is to produce smaller particles from larger ones.
- Smaller particles are the desired product either because of their large surface area or because of their shape, size & number.

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Other objectives of size reduction include:

1. To increase surface area of solids to enhance the rate of dissolution.
2. To meet stringent specifications of the sizes of commercial products,
3. To accomplish and improve intimate mixing of solids in a solid-solid operation.
4. To increase the therapeutic effectiveness of certain drugs.
5. To improve physical appearance, flowability, and compression and dose uniformity of products.
6. To enhance stability of dispersed system such as emulsions and suspensions.

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Advantages of Size Reduction

1. **Content Uniformity:** Mixing turns out effective only when the ingredients are small and of uniform size.
2. **Uniform flow:** If the size of particle is small, the flow of powder into dies during the umpression of tablets is effective,
3. **Effective extraction of drugs:** Penetration of solvent into time or cells of organic origin becomes rapid when the particle size is smaller,
4. **Effective drying:** If the size of granules is small, then the drying of granular mana becomes rapid,
5. **Improved physical stability:** In suspensions and emulsions, the rate of sedimentation decreases if the particles are of small and uniform size.
6. **Improvised rate of dissolution:** When the surface area is larger than the dissolution of substand increases. Thus size reduction facilitates in increasing the surface area.
7. **Improved absorption rate:** Smaller the particle, the faster is the absorption is the absorption because the dissolution is also enhanced,

Disadvantages of Size Reduction

1. **Drug degradation:** Decomposition of drug can occur due to the excessive heat production during milling. Another reason is increased surface area also contributes in drug decomposition.
2. **Poor mixing:** Generally, very fine particles are subjected to strong cohesive forces hence aggregation of particles takes place. But this aggregation inhibits the efficient blending of different ingredients.

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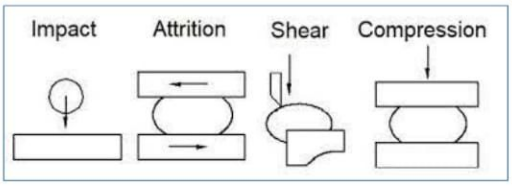
Mechanisms of Size Reduction



- **Impact** —particle is more or less stationary and is hit by an object moving at high speed(hammer)
- **Compression**—particle is crushed by two rigid forces (nutcracker).
- **Shear or cutting** —the material is crushed by means of a sharp blade or blades
- **Attrition** —breaking the edges of the solid either by impact or particle collisions or arising from particles scraping against one another or against a rigid surface (a file).

Table.1: Mechanism of Size reduction

Sr. no.	Modes	Description	Type of material	Mill following the given mode
1.	Cutting	Material is cut by the means of sharp blades	Fibrous and waxy substances	Cutter mill
2.	Compression	Material is crushed between the rollers by applying pressure	Soft materials	Roller mill
3.	Impact	In this, the substance is subjected to hammers or bars at high speed. Impact also occur when a forceful particle is strike against a stationary object	Almost all drugs are size reduced by hammer mill. Fluid energy mill is used for moderately hard and friable materials	Hammer mill Fluid energy mill Ball mill
4.	Attrition	In this, breaking of material occur y rubbing it between two surfaces	Brittle drugs	Ball mill Fluid energy mill

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Hammer Mill

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Hammer Mill

- A hammer mill is an essential machine in the pharmaceutical industries. It is used to crush, pulverize, shred, grind and reduce material to suitable sizes.

Principle:

1. It only requires choosing an appropriate motor, crushing hammers/knives and material you intend to crush.
2. It operates on the principle of impact between rapidly moving hammers mounted on rotor and the stationary powder bed.
3. The material is crushed and pulverized between the hammers and the casing and remains in the mill until it is fine enough to pass through a sieve which forms the bottom of the casing.
4. Both brittle and fibrous materials can be handled in hammer mills, though with fibrous material, projecting sections on the casing may be used to give a cutting action.

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Hammer Mill

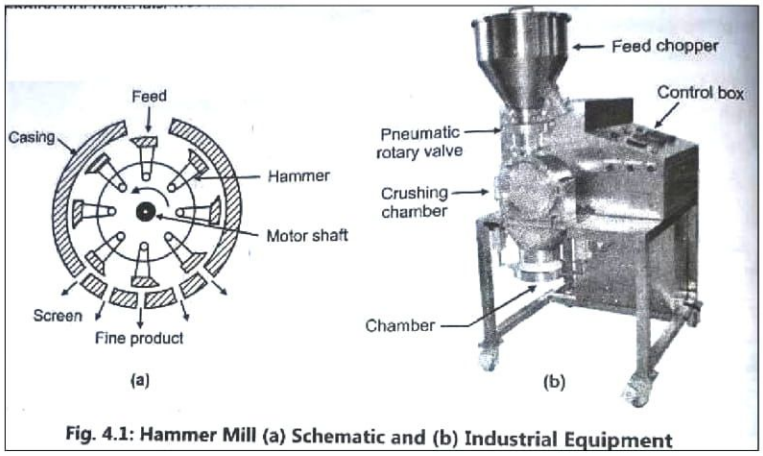

Fig. 4.1: Hammer Mill (a) Schematic and (b) Industrial Equipment

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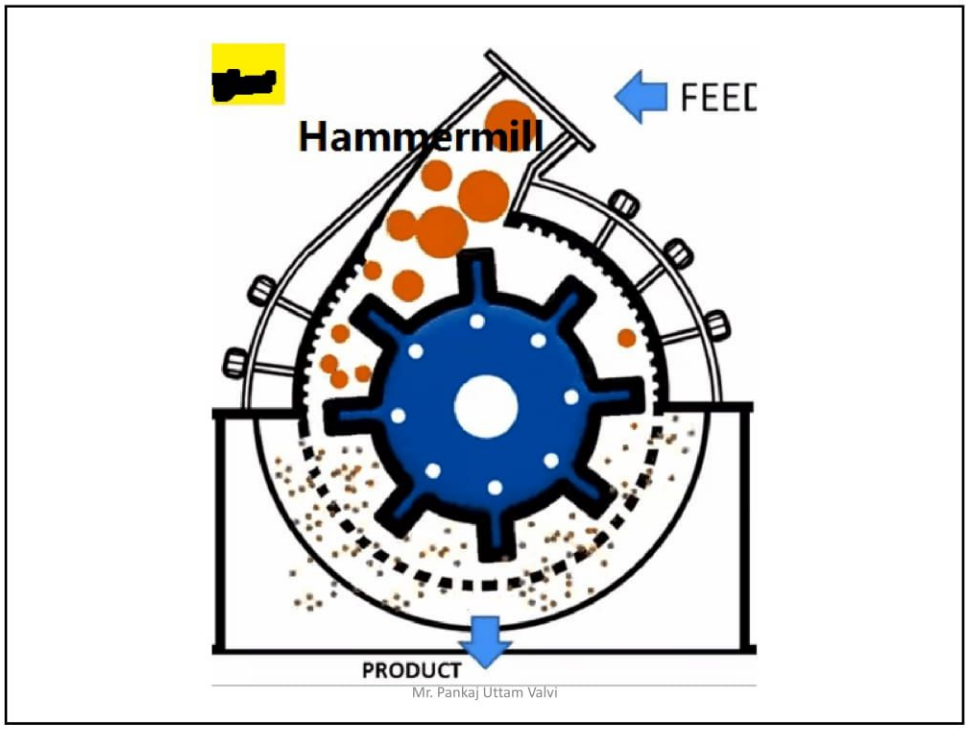

Construction:

1. Hammer mill has five main parts.
2. Normally, the number of parts may vary depending on the complexity of the machine design.
3. Every part in the hammer mill plays an integral role in the overall working of hammer mills.
4. However, the milling process mainly takes place in the crushing chamber. It consists of a stout steel casing in which a central shaft is enclosed to which four or more swinging hammers are attached.
5. When the shaft is rotated by motor the hammers swing out to a radial position.
6. On the lower part of the casing a sieve of desired size is fitted which can be easily replaced according to the particle size required.

Construction:

7. The material is crushed and pulverized between the hammers and the casing and remains in the mill until it is fine enough to pass through a sieve.
8. Some mills consist of projecting sections on the casing used to give a cutting action if fibrous materials are to be processed.
9. The hammer mills are available in various size, designs and shapes.
10. In pharmaceutical industry, they are used for grinding dry materials, wet filter cakes, ointments and slurries.

Hammer Mill

Working:

1. Feeding mechanism refers to the process by which particles enter the crushing chamber.
2. Depending on the design of the hammer in mill, it may use either gravity or a metered feeding system.
3. In the gravity feeding system, the milling machines solely depend on the gravitational force that helps to feed particles into the crushing chamber.
4. Users can switch ON/OFF the machine and may control the feeding system or motor speed from the control box.

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Hammer Mill

Working:

6. Some pharmaceutical milling machines has display panel to monitor all parameters. This mill operates at a high speed from 2,500 to 60,000 r.p.m.
7. The swinging hammerheads are attached to a rotor that rotates inside a hard casing.
8. In most cases, hammers are mounted on horizontal shafts where they may rotate either clockwise or anti-clockwise.
9. A rotor is the rotating shaft coupled to an electric motor.
10. The hammers come in different styles and shapes.
11. The motor belt can cushion it from shock and allows for accurate speed adjustment.
12. The output size of the particles depends on the sieve variation.
13. Hammer mills may have over 12 different types of sieve meshes.

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Hammer Mill

Applications:

1. Hammer mills can be used to crush fibrous materials using its cutting edges.
2. It can be used to fracture brittle material by impact of blunt hammers.
3. It can be used to produce intermediate grades of powders of almost all substances.
4. It is suitable for powdering of barks, leaves, roots, crystals and filter cakes.
5. Used in granulation where to cut damp mass into granules.

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Ball Mill

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Ball Mill

1. A pharmaceutical ball mill is a type of grinder used to grind and blend materials while manufacturing various dosage forms.
2. The size reduction in ball mill is done by impact as the balls drop from near the top of the shell.
3. According to the need ball mill can be either wet or dry designs.
4. Ball mills have been designed in standard sizes of the final products between 0.074 mm and 0.4 mm in diameter.

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Principle:

1. The size reduction in ball mill is a result of fragmentation mechanisms (impact and attrition) as the balls drop from near the top of the shell.
2. Mixing of feed is achieved by the high energy impact of balls. The energy levels of balls are as high as 12 times the gravitational acceleration.
3. Rotation of base plate provides the centrifugal force to the grinding balls and independent rotation of shell to make the balls hit the inner wall of the shell.
4. The operating principle of the ball mill involves feeding of material through the central hole into the drum (shell) that moves along with grinding media (balls).

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5. As the shell rotates the balls are lifted up on the rising side of the shell and cascade down (or drop down on to the feed) from near the top of the shell.
6. The material grinding occurs during impact of falling grinding balls and abrasion of the particles between the balls.
7. In ball mill depending on the rotational speed following possible modes of the grinding media motion could be achieved.

a) Low speed:

Speed mode with a rolling of grinding balls without flight.

b) Mixed mode (Cascade mode motion):

Speed mode with a partial rolling and a partial flight of grinding balls.

c) High speed:

Speed mode with circular motion of balls with no fall.

8. The speed of the rotation is more important. At a low speed, the mass of the ball slides or rolls over each other with inefficient output.
9. At a high speed, the balls are thrown out to the walls by centrifugal force.
10. Since at this speed there is absence of any impact or attrition no grinding occurs.

8. Compression by the ball against the shell wall is not enough for comminution.
9. But at 2/3 of the speed (50 to 80% of the critical speed Fig. 4.2 (c), the centrifugal speed force just occurs with the result that the balls are carried almost to the top of the mill and then fall to the bottom.
10. This way, the maximum size reduction is affected by the impact of particles between the balls and by attrition between the balls.

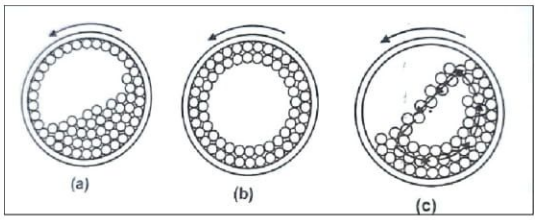
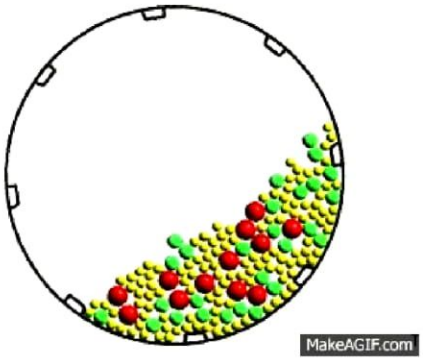


Fig. 4.2: Cascade Operation in Ball Mill (a) Low Speed (b) High Speed (c) Correct Speed

Correct Speed



Ball Mill

Construction:

1. The most commonly used ball mills used for different pharmaceutical applications are pebble ball mill and vibrating ball mill.
2. A typical ball mill consists of a hollow cylindrical shell (drum) containing balls mounted on a metallic frame such that it can be rotated along its longitudinal axis.
3. The axis of the shell may be either horizontal or at a small angle to the horizontal.
4. It is partially filled with balls, which may be made of chrome steel, stainless steel or ceramic.
5. The balls which could be of different diameter occupy 30 - 50% of the mill volume and its size depends on the feed and mill size.

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Ball Mill

7. The ball size depends on the feed and the diameter of the mill.
8. The inner surface of the cylindrical shell is usually lined with an abrasion-resistant material such as manganese steel or rubber.
9. The coated metallic drum provides attrition force.
10. The length of the mill is approximately equal to or slightly greater than its diameter.

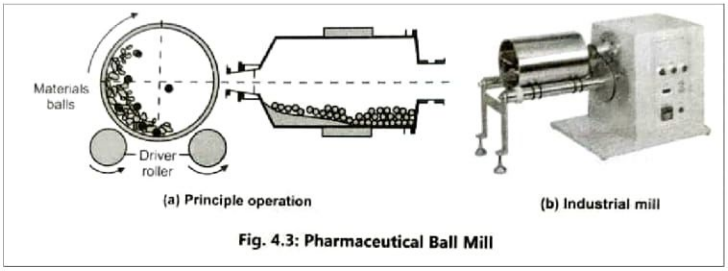

Fig. 4.3: Pharmaceutical Ball Mill

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Working:

1. Ball mills differ to an extent in their operating principle.
2. Large to medium ball mills are mechanically rotated on their axis, but small ones normally consist of a cylindrical capped container that sits on two drive shafts.
3. The steps involved in the working process of ball mill are as follows:
   A. Initial Stage
   B. Intermediate Stage
   C. Final Stage
   D. Completion Stage

A. Initial stage:

- Powder particles get flattened by the collision of the balls.
- It leads to changes in the shapes of individual particles or cluster of particles being impacted repeatedly by the milling balls with high kinetic energy.

B. Intermediate stage:

- A significant change in size of material occurs in comparison with those in the initial stage.

C. Final stage:

- Reduction in particle size takes place to fine size.
- The microstructure of the particle also appears to be more homogenous at microscopic scale than those at earlier two stages.

D. Completion stage:

- The powder particles possess an extremely deformed metastable structure.

Advantages of ball mill includes:

1. Simple Design,
2. Ease of Examination,
3. Change of Abraded Spare Parts,
4. Reliable and Continuous Operation,
5. Suitable for Wet and Dry Grinding,
6. Easy Maintenance and Management.

Applications:

1. Small capacity ball mills are used for wet grinding, for example, suspensions.
2. The high capacity ball mills are used for milling ores.
3. Ball mills are an efficiently used in grinding many brittle, sticky and amorphous materials into fine powders.
4. Ball mills are used for grinding of hard and abrasive as well as wet and dry materials for pharmaceutical purpose.
5. These mills are used to grind powders for ophthalmic and parenteral products, milling of pigments and insecticides for industrial purpose.
6. Rubber ball mills are used for blending of explosive materials.
7. Ball mills are used to effectively increase solid-state chemical reactivity.

Reference

- A Textbook of Pharmaceutics by Dr. Ashok Hajare, Nirali Prakashan

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